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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 :		(11) International Publication Number:
E21B 23/00, 47/00	A1	WO 93/18277
		(43) International Publication Date: 16 September 1993 (16.09.93)

(21) International Application Number: PCT/DK93/00092

(22) International Filing Date: 12 March 1993 (12.03.93)

(30) Priority data:
0341/92 13 March 1992 (13.03.92) DK

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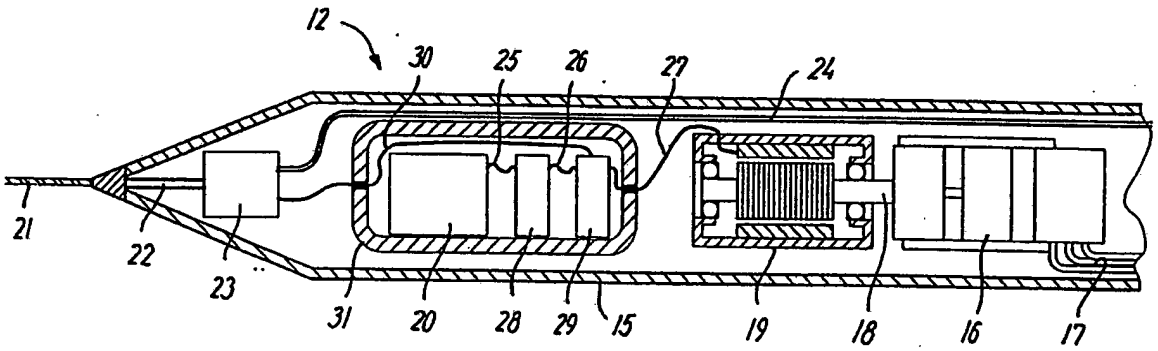
(81) Designated States: AT, AU, BB, BG, BR, CA, CH, CZ, DE, DK, ES, FI, GB, HU, JP, KP, KR, KZ, LK, LU, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SK, UA, US, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, SN, TD, TG).

Published
With international search report.
In English translation (filed in Danish).

(54) Title: A TRACTOR FOR ADVANCING PROCESSING AND MEASURING EQUIPMENT IN A BOREHOLE



(57) Abstract

A hydraulically driven tractor (4) serves to advance processing and/or measuring equipment (5) in subterranean formation (1). The tractor (4) comprises a section (12) which is filled with hydraulic oil and contains a hydraulic pump (16) for the hydraulic system (17) of the tractor, an electric motor (19) for operating the pump (16) and a battery (20) for energizing the motor (19). The motor (19) is an open AC motor, and a converter (28) for converting the DC current from the battery to AC current is inserted between the motor and the battery (20). The battery (20) and the converter (28) are incorporated in an air-filled pressure container (31). The tractor is suitable for working under the extremely high temperatures and pressures which prevail in a deep borehole. Considerable economic and time benefits are obtained by using the tractor instead of a drill string for advancing the measuring tools in the borehole.

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A tractor for advancing processing and measuring equipment in a borehole

The invention concerns a hydraulically driven tractor for advancing processing and/or measuring equipment in a predrilled hole in a subterranean formation, comprising a section filled with hydraulic oil and containing a hydraulic pump for the hydraulic system of the tractor, an electric motor for operating the pump and a battery for energizing the motor.

Boreholes for exploitation of oil and gas frequently extend many kilometers into the underground to reach and penetrate the oil and gas bearing strata. Information for the planning and control of the production must be obtained from these not very accessible regions deep below the surface where extremely high temperatures and pressures prevail. This information is i.a. to tell about the type of the formation, its porosity and permeability as well as content of oil, gas and water, and also various tasks may have to be performed, such as perforation of an existing casing and operation of valves in it.

With this end in view an abundant range of equipment has been developed in the course of time in the form of measuring tools and instruments, which are capable of resisting the high temperatures and pressures in a deep borehole, and which moreover have a configuration such that they can pass through it. Generally, a plurality of interconnected tools having a rather considerable overall length of frequently about 20 to 30 meters and a weight of e.g. 1500 kg are simultaneously passed down into the borehole. Equipment of this type can readily be lowered in a wire line solely under the action of gravity, wh n the borehole extends vertically or with a minor inclination

with respect to the vertical, but in case of greater inclinations above about 60° the equipment settles on the bottom of the borehole. This situation occurs frequently, since many of the interesting strikes are present precisely in the more or less horizontally extending strata in the underground.

A known method of solving this problem comprises the use of a thin-walled steel pipe wound on a drum and pressurized to obtain a sufficiently great stiffness. By successively unwinding this steel pipe from the drum and subjecting it to a pressure force equipment of the above-mentioned type can be pushed a distance of between 500 and 900 meters into a horizontal borehole.

However, with the advanced technology used today the boreholes are very frequently drilled with a considerably greater length. In these cases it is common to use the actual drill string for advancing the equipment in the borehole. The equipment is then threaded on to the end of the drill pipes, following which the drill string is assembled. The electric wires, which connect the instruments with the station on the surface, extend on the outer side of the drill string and are run into the various instruments via inserted intermediate pipes in the drill string. The equipment can be moved relatively far into a horizontal borehole by means of this method, but on the other hand the process is cumbersome and slow. With a borehole having an overall length of 5000 meters, of which half extends with an inclination of above 60° with respect to the vertical, the time spent will thus typically be about 24 hours.

A natural solution might comprise using a self-propelling tractor of the type which is described in the Applicant's international patent application PCT/DK89/00213, for pull-

ing or pushing the measuring equipment through the borehole. This tractor is intended to exert the necessary pressure on a drill bit while pulling the drill string after it in the drilled hole, and it thus has a considerable traction force. The wheels of the tractor are pressed against the wall of the borehole and are caused to rotate by means of a hydraulic system having a hydraulic pump, which is normally driven by a mud motor when the tractor is used in connection with a drilling operation. If the tractor is to be used solely for advancing measuring tools in the borehole, no drilling mud is available for driving a mud motor, and instead this may expediently be replaced by an electric motor.

The power supply for such an electric motor may e.g. be obtained from the surface via a cable which, however, is usually not capable of transferring a power greater than about 500 watts, partly because the cable is wound on a drum, partly because it offers great resistence owing to its length. In case of long boreholes a considerable voltage drop must thus be expected along the cable, so that an applied voltage of 600 volts at the surface may be reduced to 150 volts down in the borehole where the tools are present. To this should be added that owing to the safety of the personnel it is a requirement that only relatively small voltages and current intensities are used.

A solution to these problems might be that the tractor brought its own power supply in the form of a battery which, however, cannot, or only with great difficulty, operate directly under the extremely servere working conditions in the borehole, and a battery supplying DC is not useful as a power source for an electric motor which is to be capable of working in the same difficult environment. The new and unique features of the invention remedying

these drawbacks are that the motor is an open AC motor, that a converter is inserted between the motor and the battery for converting the DC of the battery to AC, and that the battery and the converter are incorporated in an air-filled pressure container.

Furthermore, a control relay may advantageously be incorporated in the pressure container to start and stop the motor via signals through the cable from the surface, as desired.

The invention will be explained more fully by the following description of an embodiment, which just serves as an example, with reference to the drawing, in which

fig. 1 schematically shows a fraction of a vertical section through a subterranean formation with a borehole in which a self-propelling tractor pulls a number of measuring tools,

fig. 2 schematically shows the tractor of fig. 1 on an enlarged scale, and

fig. 3 shows a fraction of a section for the tractor of figs. 1 and 2 with its power assembly.

Fig. 1 shows a subterranean formation 1 with a borehole 2, which initially extends vertically down into the formation and then through a bend horizontally. A tractor 4 drives in the borehole, pulling a trail 5 of three hooked-up measuring tools. A tower 6 with a drum 7 is mounted on the surface 3 and on the borehole 2, a wireline 8, whose lowermost end is connected with the measuring tool trail 5, being wound on said drum. The wireline 8 is in turn connected via an electric connection 9 with a measuring station, which, in this case, is in the form of a vehicle

containing the nec ssary means for recording and interpreting the measurement signals received from the borehole.

Fig. 2 is an enlarged view of the actual tractor 4 with a portion of the front part of the trail 5 being indicated in dashed lines. The tractor 4 substantially consists of a front traction section 11 and a rear power section 12. The traction section 11 may e.g. be arranged like the apparatus described in the Applicant's previously mentioned international patent application PCT/DK89/00213, it being observed that the invention can be used in connection with any appartus of this type. The traction section 11 is self-propelling and has wheels 13 capable of running on the wall 14 of the borehole. The wheels are driven by a hydraulic system which likewise keeps the wheels pressed against the wall of the borehole, so that they can transfer the necessary traction force to it.

Fig. 3 shows an enlarged section through the power section 12 of the tractor. Outwardly this has a wall 15 and is filled with hydraulic oil under pressure, which may e.g. be 1300 bars in deep boreholes. A compensator (not shown), which is of a known type and will therefore not be mentioned more fully here, is provided in the power section to equalize the pressure with respect to the surroundings. The power section comprises a hydraulic pump 16 inserted with hydraulic pipes 17 into the hydraulic circuit of the traction section 11 to the wheels 13. The hydraulic pump 16 is driven via a shaft 18 by an electric motor 19. A battery 20 serves to energize the motor 19. The power section is connected with the measuring tools and measuring station on the surface via a wire 21 having the necessary electric cables 22, which are run into a cable distributor 23 and from this via other electric cables 24 to optional measuring tools arranged in front of

the tractor. The battery is connected by electric cables 25, 26 and 27, respectively, to the electric motor 19 via an electric converter 28 and a control relay 29, which is in turn connected with the measuring station 10 on the surface via a control line 30, the cable distributor 23 and the electric cables 22.

As mentioned, the power section 12 is filled with hydraulic oil under a very high pressure, which may be up to 1300 bars, and it will therefore not be expedient to use a fully encapsulated electric motor whose shaft lead-in will have difficulty in maintaining a tight seal against the huge pressure difference. The electric motor 19 is therefore of an open design and interiorly completely filled with hydraulic oil. A DC motor is not suitable for working with the commutator thus immersed in oil, and instead an AC motor is used without a commutator. The DC current from the battery 20 is therefore converted to AC current in the converter 28 before being fed to the electric motor 19.

The battery 20, the converter 28 and the control relay 29 are moreover encapsulated in an air-filled pressure container 31, since these electric components cannot stand being exposed in the hydraulic oil because of i.a. the high pressure in it.

Just a start and stop signal is required for controlling the tractor, applied to the control relay 29 from the measuring station on the surface via the wireline 21 and the control line 30. Another way of controlling the tractor is to incorporate a timer (not shown) in it for starting the tractor after e.g. half an hour and stopping it again when a touch sensor (not shown) engages the end of the hole.

A tractor for an 8 1/2" borehole may typically have the following specifications:

Max outside diameter	149 mm
Nominal diameter	140 mm
Length	3-4 m
Weight max	200 kg
Weight incl. buoyancy max	100 kg
Power requirement max	5.0 kW
Power requirement average	1.2 kW
Battery amount minimum	5 kWh
Speed constant	1000 m/h
Force forward max	15 kN
Wash outs	280 mm
Hydrostatic pressure max	1300 bars
Temperature max	150°C
Tensile strength	30 kN

The above-mentioned tractor will be capable of pulling 20 to 30 meters of measuring tools as well as a minimum of 3000 of wireline having a total weigth of about 1500 kg in a horizontal borehole.

To ensure undisturbed operation of the wireline drum on the surface it will expedient that the tractor drives forwardly in the borehole at a constant speed, irrespective of the load, so that the wireline correspondingly runs in the hole at a constant rate over the distance in which the tractor is active. Normal down rate of the standard measuring tools is about 3000 m/h, and a normal retraction rate with the wireline is about 600 m/h. The speed of the tractor is expediently fixed at 1000 m/h to limit the power requirement.

In the previously mentioned borehole having an overall depth of 5000 met rs, of which half had an inclination of

above 60°, the time it took the drill string to advance the measuring tools was about 24 hours. Instead, using the tractor of the invention with the above-mentioned specifications this time can typically be reduced to 8 hours, thus providing a time saving of about 16 hours.

Patent Claims:

1. A hydraulically driven tractor for advancing processing and/or measuring equipment in a pre-drilled hole in a subterranean formation, comprising a section filled with hydraulic oil and containing a hydraulic pump for the hydraulic system of the tractor, an electric motor for operating said pump and a battery for energizing the motor, characterized in that the motor is an open AC motor, that a converter for converting the current to AC current is inserted between the motor and the battery, and that the battery and the converter are incorporated in an air-filled pressure container.

2. A tractor according to claim 1, characterized in that the pressure container moreover incorporates a control relay.

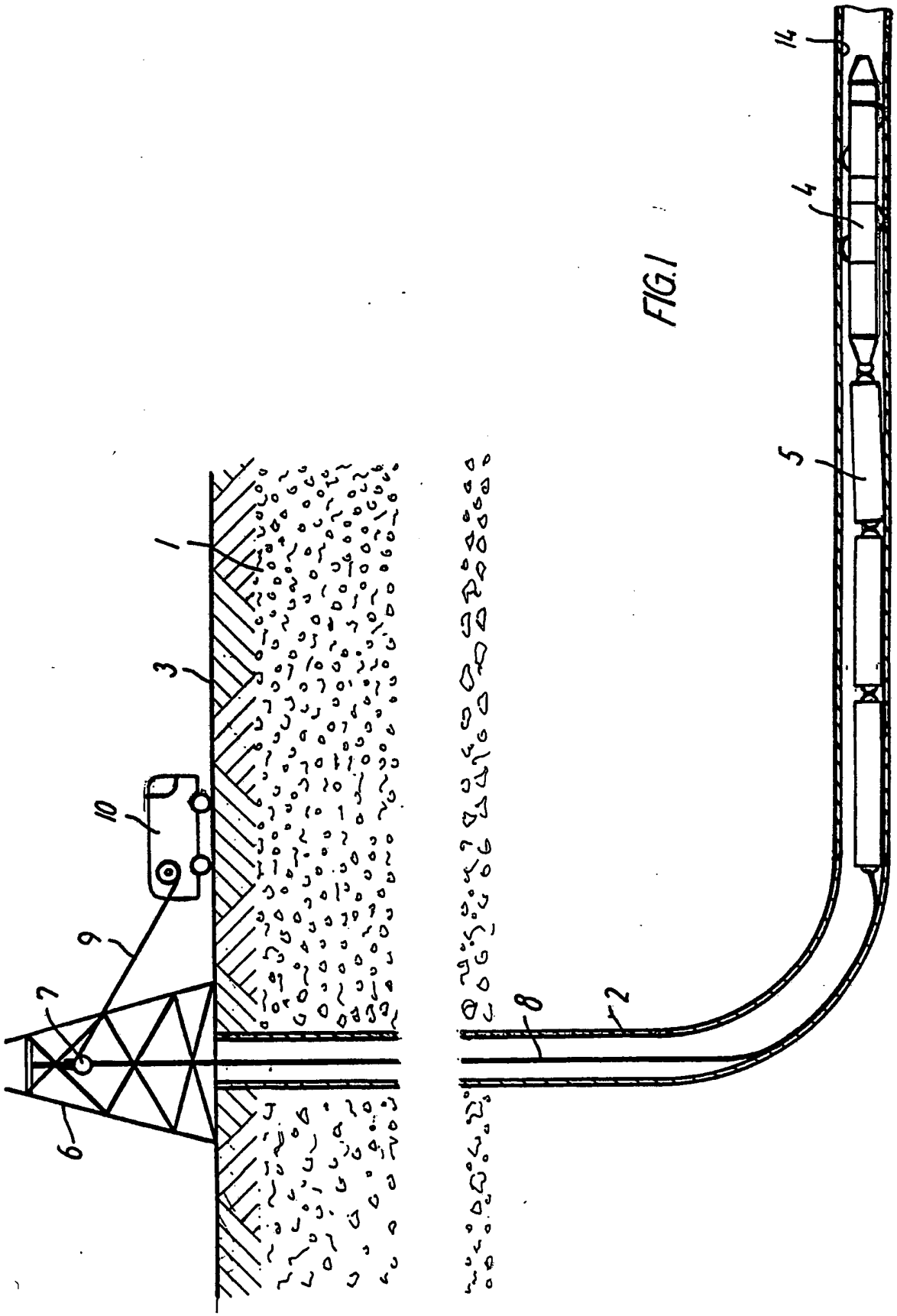

FIG.1

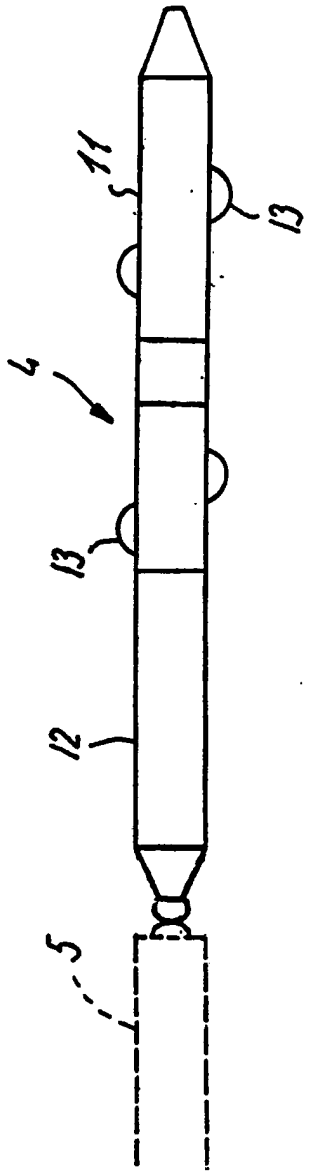

FIG.2

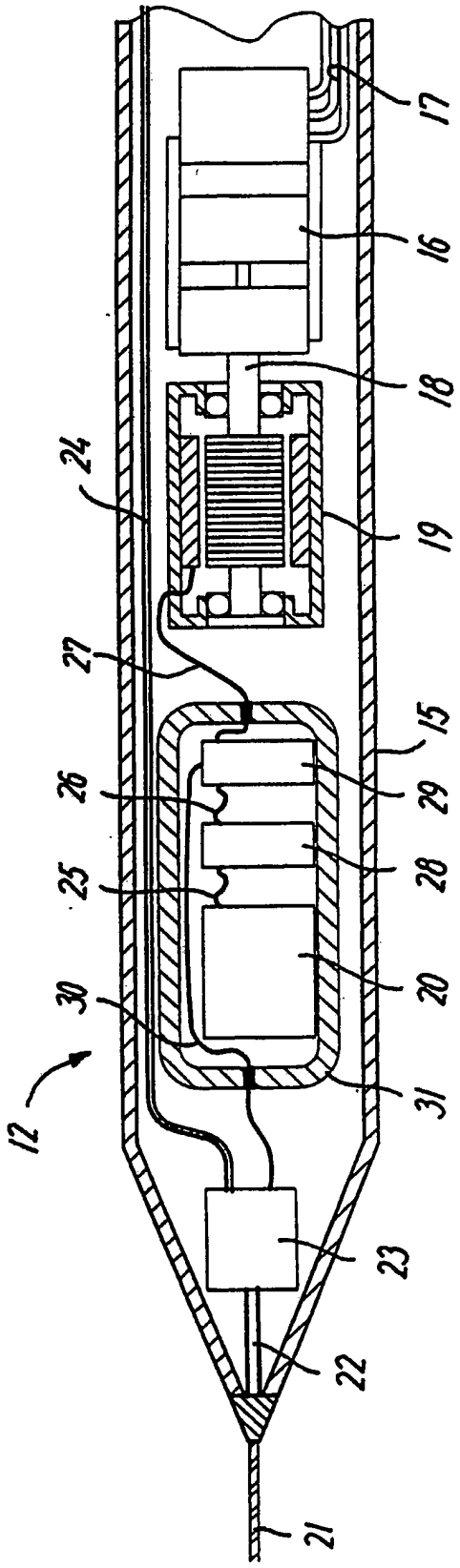

FIG.3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 93/00092

A. CLASSIFICATION OF SUBJECT MATTER

IPC5: E21B 23/00, E21B 47/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC5: E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DK, B, 137935 (MOBIL OIL CORPORATION), 5 June 1978 (05.06.78), page 7, second paragraph --	1-2
A	US, A, 3433986 (A. ARUTUNOFF), 18 March 1969 (18.03.69), column 1, line 21 - line 40 --	1-2
A	US, A, 4833354 (C.S. MILLER), 23 May 1989 (23.05.89), column 2, line 51 - line 66 --	1-2
A	US, A, 4763259 (L.C. DELATORRE ET AL), 9 August 1988 (09.08.88), column 2, line 61 - column 3, line 3 --	1-2

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
14 June 1993	15 -06- 1993
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, A, 4499955 (F.L. CAMPBELL ET AL), 19 February 1985 (19.02.85), column 6, line 21 - line 45	1-2

INTERNATIONAL SEARCH REPORT

Information on patent family members

28/05/93

International application No.
PCT/DK 93/00092

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DK-B- 137935	05/06/78	NONE	
US-A- 3433986	18/03/69	NONE	
US-A- 4833354	23/05/89	CA-A- 1312109	29/12/92
		DE-A,C- 3916253	14/12/89
		FR-A- 2632787	15/12/89
		GB-A,B- 2220527	10/01/90
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US-A- 4763259	09/08/88	NONE	
US-A- 4499955	19/02/85	NONE	